Spiny-cheeked Honeyeater *(Acanthagenys rufogularis)*.—Only two pairs seen, both in the railway station yard.

Australian Pipit *(Anthus novæ-seelandiæ)*.—Restricted to cultivated land, and the railway reserve.

Zebra Finch *(Poephila castanotis)*.—A small flock seen in the station yard on one occasion. Old nests were noted several times.

Crow *(Corvus sp.)*.—Flocks were noted throughout the area. Since I was not able to examine a specimen, the birds were not positively identified.

Squeaker *(Strepera versicolor)*.—Only one pair was seen; these resided in the timber adjacent to the dam.

Grey Butcher-bird *(Cracticus torquatus)*.—This was the common butcher-bird in the area. A family party was located in the station yard, and became very confiding, coming inside the hut for meat scraps or cheese.

Pied Butcher-bird *(Cracticus nigrogularis)*.—Seen on only two occasions.

Western Magpie *(Gymnorhina dorsalis)*.—Only one flock of 8 individuals in the township area—none was seen in the surrounding country.

PRESENT CLIMATIC FLUCTUATIONS IN WESTERN AUSTRALIA

By J. GENTILLI, Nedlands.

Biogeographers have repeatedly noticed slight changes in the geographical distribution or in the habitats of some species, or in the relative abundance of communities or individuals. There have been records of "invasions" of wet areas by "dry" species, and there have been records of the dying out of certain communities over small areas which have become unsuited to their continued existence.

It is too easy to blame or thank Man for these changes. It is quite possible that the abundance of very young individuals of the Western Flooded Gum *(Eucalyptus rudis)* may be due to lack of competition by other species which have been cut down too ruthlessly by Man, but is there any proof of this fact? Does not *Eucalyptus rudis* grow where the ground water comes so close to the surface that no other local species of *Eucalyptus* could survive? Around several swamps which have gradually become lakes, Paperbarks *(Melaleuca)* have died, literally drowned. Obviously the water table has come closer to the surface. But is this a change restricted to the Perth area, or is it only part of a general change which affects large regions or perhaps the whole continent? Over large regions of Western Australia a change is quite apparent, namely the rise of salt to the surface of the soil. It is a problem which has baffled expert opinion for years. Perhaps the clearing of the native vegetation has altered the delicate hydrologic balance of the ground, so that the water table has come nearer to the surface thus enabling the water to creep upwards by capillarity, finally evaporating and leaving its salt load at the surface of the soil. Could the rise of the water table be due to an increased rainfall, perhaps combined with the clearing of the native vegetation?

An objective study of some of the climatic material available provides some interesting evidence of climatic changes, which may not be part of any long-term trend, or any established cycle, but are there nonetheless, and are of sufficient import to warrant further study and careful planning in case the trend thus disclosed happens to continue into the future.

THE METHODS USED

The study of any changes in time-series may be carried out by drawing suitable graphs and analyzing them, but this method is open to errors due to the scales adopted, the accuracy of the graph, and the individual worker. Mathematical methods are more reliable, and among these the method of moving averages has been used by many research workers, among whom might be quoted Ahlmann and his school. This method consists of taking the average (arithmetic mean) of a short series of data then dropping the first item of the series and adding the next item after the last and computing the new average, and so on. Five-year averages are usually adopted because they are readily computed, and are centred on the central year of each series. Seven-year averages may also be computed, but since in this case the central year of the initial series is the fourth year, the first three years (and the last three years) of the whole sequence are lost.

The method of moving averages has the advantage of showing all the major variations within the sequence, while at the same time smoothing out the minor fluctuations within each short series. It is a flexible method which follows the original data rather closely, and for this reason long-term trends must be determined by other methods, which although strictly based upon all the items in the sequence, do not follow single fluctuations too closely. The computation of semi-averages is perhaps the easiest of these methods, because it involves computing the separate averages of the first and second half of the whole sequence, and plotting the straight line between the two points thus determined. The method however does not lend itself to any further mathematical treatment, and in any case can only yield a straight line. The method of least squares (so called because in any case the line obtained is such that the squares of the differences between the points on this line and the corresponding points in the original sequence are smaller than the squares obtained by using any other line) is mathematically sound, based on every item in the sequence, and capable of further development. In some cases it has been thought better to use this method, although it involves a slightly greater amount of work.

THE RAINFALL OF PERTH

Records of rainfall are available from 1877 onwards, but there is a break in the series due to the opening of the new Observatory in 1897. Before that year the observations had been made in the Government Gardens, very near the Swan River. The Observatory, built on a hill, is not only higher above sea level, but also differently exposed to the weather. A statistical analysis showed that observations of the *quantity* of the rainfall in the two localities hardly showed any significant difference, whereas observations of the *number of wet days* disclosed a substantial difference, so that Government Garden records and Observatory records should be treated separately for that purpose. The treatment of data on the quantity of the rainfall as a continuous sequence, i.e., using the data from Government Gardens from 1877 to 1896 and the data from the Observatory from 1897 onwards, seems therefore justified (official statistics do this for all records, including those in which the two localities actually differ).

The mean annual rainfall for the period 1877-1945 was found to be 34.85 inches. The least-square straight line passes through 32.56 inches in 1877 and 37.14 inches in 1945, showing an increase of 4.59 inches or 14.1 % during the 69-year period.

The same statistical treatment gives the following values for the monthly rainfall:

TABLE 1.—COMPUTED LEAST-SQUARE VALUES OF MONTHLY RAINFALL, PERTH

Month	1877 points	Mean points	1947 points	Change 1877-1947 points	%
January	40	33	26	−14	−35
February	49	39	29	−20	−41
March	63	82	101	+38	+60
April	158	173	188	+30	+19
May	483	507	531	+48	+ 9
June	586	709	832	+246	+42
July	597	671	745	+148	+25
August	564	572	580	+16	+ 3
September	319	339	359	+40	+11
October	205	218	231	+26	+12
November	76	76	76	0	0
December	58	55	52	− 6	−12

The table discloses that summer rainfall (December to February) has slightly decreased, whereas the rainfall of winter type (April-October) has increased considerably. The increase has reached the highest value in June, with 246 points for the 71 years—42% of the initial amount. The increase in the July rainfall, 148 points (25%) comes next. The increase in the May rainfall, 48 points (9%) is much smaller, and the increase in the August rainfall, 16 points (3%) is the smallest of all those experienced in the cooler months. The very high percentage increase in the March rainfall (60%) may be mostly due to chance, because this month falls between the summer and winter types of rain.

A change in the regime of the rainfall is also evident. In the values computed for 1877 July was the wettest month, and the decrease from July to August was not very great. Now June is the wettest month, and the rainfall in August has hardly changed.

TABLE 2.—MONTHLY RAINFALL REGIME, PER CENT. OF ANNUAL TOTAL.

	J.	F.	M.	A.	M.	J.	J.	A.	S.	O.	N.	D.	Year
1877	1.2	1.5	2.0	4.9	15.5	18.3	18.7	17.6	10.0	6.4	2.4	1.8	100.0
1947	.7	.8	2.7	5.0	14.2	22.2	19.9	15.5	9.6	6.2	2.0	1.4	100.0

Table 2 shows that August, which received 17.6% of the year's rainfall at the beginning of the period under observation, now receives 15.5. The decrease is only relative, because the total rainfall for the month has not decreased at all, but it may be quite significant for plant and animal life that August and September received 27.6% of the annual amount of rain in 1877 and receive 25.1 now. The months from August to February received 40.9% of the annual rainfall in 1877, but the same months now receive only 36.2% of the annual total.

Even though the amount of summer rain has decreased slightly, there is no evidence of any greater severity of summers. Some data have been collated and are shown below:

TABLE 3.—NUMBER OF DRY MONTHS PER DECADE, PERTH.

Decade	Months with less than 25 points	Months with 25 to 50 points	Months with 50 to 75 points	Months with 75 to 100 points	Months with less than 50 points	Months with 50 to 100 points	Total Dry months
1877-1886 . .	19	2	14	9	21	23	44
1887-1896	25	7	7	8	32	15	47
1897-1906	25	14	7	3	39	10	49
1907-1916	23	14	4	7	37	11	48
1917-1926 ...	20	7	6	8	27	14	41
1927-1936	24	14	3	8	38	11	49
1937-1946	26	7	5	3	33	8	41

The number of very dry months has hardly changed. The years with *five* consecutive months with less than 25 points of rain each were 1877, 1891, 1902, 1920, 1932. In addition, 1911 had *four* of these very dry months. Obviously there is no trend that can be detected in this series. The number of months with 25 to 50 points of rain shows some increase, and conversely that of months with 50 to 75 points shows a decrease. Whether the changes are significant, and whether they disclose a definite trend or are just due to chance, only future observations can tell.

It is clear that some changes have taken place in the rainfall of Perth, and some of these changes are of sufficient significance to alter the climatic environment to a noticeable extent.

THE RAINFALL OF ALBANY

A partial analysis of trends in the rainfall of Albany was carried out by Mr. Ross Ewen in the course of his studies at the Geographical Laboratory of the University of Western Australia. Rainfall records for the 73 years from 1877 to 1949 were partly obtained from published data and partly made available by the courtesy of the Weather Bureau, Perth, so that a sufficiently long series was available for the computation of the least square trend-line.

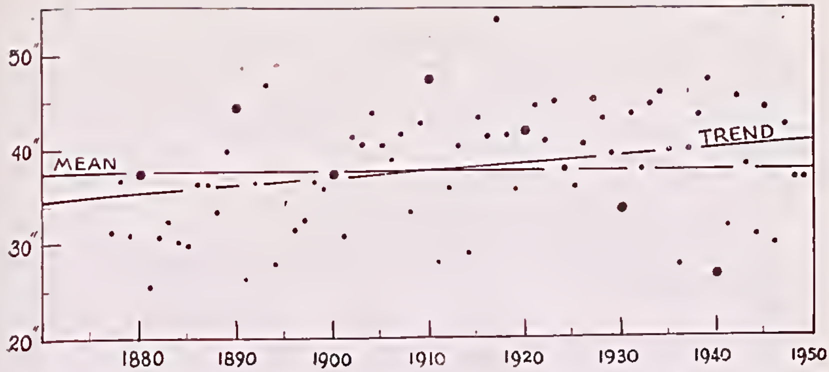

Fig. 1.—The rainfall of Albany. The graph shows the actual rainfall of Albany for the period up to 1949. The smaller dots show the actual rainfall for each year, and the first year of each decade is shown by a larger dot for easy reference. The horizontal line shows the mean (average) rainfall for the period, and the sloping line shows the trend computed as explained in the text. It is clear that the increase in the rainfall took place especially at the beginning of the century, and has continued unabated until the 'twenties. Later on, very wet years have been separated by very dry years. The rainfall of the next two decades will show whether the increase has come to an end or whether the droughts have been accidental.

The total annual rainfall reaches an average of 37.57 inches, and the least-square values found were 34.33 inches for 1877 and 40.81 inches for 1949, i.e., an increase of 6.48 inches (19%) over the 73 years. This is an increase which agrees with that found for Perth, and is even more remarkable.

It was not possible through lack of time to compute trend values for each month, and the winter months were chosen for detailed study. The values found are shown in the table below:

TABLE 4.—COMPUTED LEAST-SQUARE VALUES OF MONTHLY RAINFALL, ALBANY.

Month	1877 points	Mean points	1949 points	Change 1877-1949 points	%
June	467	546	625	158	34
July	470	574	678	208	44
August	510	521	532	22	4

Remarkable changes are revealed by this table. August was the wettest month of the beginning of the period studied, but the conspicuous increase in the rainfall of June and July (amounting to nearly 57% of the increase for the annual rainfall) has now made July the wettest month, and the peak of the annual rainfall has clearly shifted to an earlier time of the year.

The same trend is disclosed by the averages for ten-year periods, and these values are given as an example of the results that may be obtained by the simpler method:

TABLE 5.—TEN-YEAR AVERAGES, MONTHLY RAINFALL, ALBANY.

Decade	June	July	August
1877-1886	4.69	4.39	5.31
1887-1896	5.47	4.98	4.99
1897-1906	5.56	5.58	5.22
1907-1916	5.42	6.74	5.59
1917-1926	5.73	5.81	4.94
1927-1936	5.65	6.38	5.57
1937-1946	5.31	6.01	5.22

Perth and Albany have similar rainfall caused by the same factors, and the analogy found between the two localities is only to be expected if these factors vary in a similar way. Because of the length of the period analyzed and because of the distance between the two localities it seems warranted to assume that the changes postulated are on a large scale and at least regional, if not global, in magnitude.

THE RAINFALL OF ONSLOW

Onslow, situated in that belt of country just reached by the winter rains as well as by the summer rains, but never well endowed with rains from either system, provides an excellent instance for further study. Mr. Peter Good, in the course of his studies at the University of Western Australia, carried out the necessary computations, the results of which are shown in the table below. The period covered, 63 years, from 1886 to 1948, is sufficiently long to give reliable results.

TABLE 6.—COMPUTED LEAST-SQUARE VALUES OF MONTHLY RAINFALL, ONSLOW.

Month	1883 points	Mean points	1948 points	Change 1883-1948 points	%
January	83	96	109	26	31
February	(—31)	106	(243)	274	......
March	60	169	278	218	363
April	98	101	105	7	7
May	172	162	152	—20	—12
June	183	157	131	—52	—28
July	79	76	73	— 6	— 8
August	48	44	40	— 8	—17
September ...	4	4	4	0	0
October	1	2	3	2	200
November ...	1	4	7	6	600
December	7	15	23	16	229

The rainfall of Onslow is too erratic for any definite trend to be obtained with any degree of certainty. A computation of the annual average rainfall based on ten-year periods, carried out by Miss Patsy Back, gave the following results:—

TABLE 7—AVERAGE ANNUAL RAINFALL FOR TEN-YEAR PERIODS, ONSLOW.

Decade	J.	F.	M.	A.	M.	J.	J.	A.	S.	O.	N.	D.
1886-1895	62	67	95	37	220	174	87	54	3	1	3	2
1896-1905	46	84	63	111	164	158	140	16	8	0	1	40
1906-1915	129	51	66	166	67	206	89	44	6	0	1	1
1916-1925	156	272	284	64	142	177	26	45	6	6	2	0
1926-1935	52	88	373	91	163	119	72	61	1	4	1	29
1936-1945	107	206	123	89	174	100	32	34	1	1	13	29

It is quite clear that some change has taken place over the period under consideration, but it would not be justified to say that this change is part of a definite trend. On the other hand, the fact that during June there used to fall over 1.5 inches of rain (on the average) during the first 40 years on record, and less than 1.2 during the last 20 years, and that in July the average of more than 85 points for the first 30 years has fallen to less than 72 points for the last 30 years, so that for instance the three winter months had an average total rainfall of 166 points during the last 10 years ending 1945, against an average of 315 points during the first 10 years (ending 1895), is likely to affect plant and animal life. Ephemeral plants will find winter more forbidding, perennial plants may find their flowering season curtailed. The changes may not be part of a trend, but they are important enough to be significant.

WET DAYS ON THE GOLDFIELDS

As a test of the general magnitude of the changes and of their geographical significance, a study was made of the number of wet days at Southern Cross, Coolgardie and Kalgoorlie during the two decades 1931-40 and 1941-50. The results are tabulated below, and show that the drier areas have experienced a slight increase in the total annual number of wet days, whereas the wetter area has experienced a decrease. The increase varies from 5.4 days per year at Coolgardie to 7.9 days per year at Kalgoorlie, and would not be so important if it did not correspond to a definite change in the winter number of wet days, a factor of great significance where the rainfall is scanty.

TABLE 8—TOTAL NUMBER OF WET DAYS PER DECADE.

Month	SOUTHERN CROSS				COOLGARDIE				KALGOORLIE			
	1931-1940	1941-1950	Difference No.	Difference %	1931-1940	1941-1950	Difference No.	Difference %	1931-1940	1941-1950	Difference No.	Difference %
January	27	24	−3	−11	30	25	−5	−17	32	21	−11	−35
February	18	35	+17	+94	21	38	+17	+81	18	33	+15	+83
March	32	35	+3	+9	33	33	0	0	38	26	−12	−32
April	36	38	+2	+6	39	38	−1	−3	39	40	+1	+3
May	70	66	−4	−6	48	67	+19	+40	42	63	+21	+50
June	88	77	−11	−13	54	80	+26	+48	41	75	+34	+83
July	103	90	−13	−13	75	86	+11	+15	58	76	+18	+31
August	89	71	−18	−21	70	69	−1	−1	66	67	+1	+2
September	51	42	−9	−18	38	42	+4	+11	33	48	+15	+45
October	55	30	−25	−45	39	31	−8	−21	34	38	+4	+12
November	39	30	−9	−23	36	27	−9	−25	34	31	−3	−8
December	23	24	+1	+4	20	21	+1	+5	32	28	−4	−13
Summer	68	83	+15	+22	71	84	+13	+17	82	82	0	0
Autumn	138	139	+1	+1	120	138	+18	+15	119	129	+10	+8
Winter	280	238	−42	−15	199	235	+36	+18	165	218	+53	+32
Spring	145	102	−43	−30	113	100	−13	−11	101	117	+16	+16
Year	631	562	−69	−11	503	557	+54	+11	467	546	+79	+17

The average 1931-40 winter had 28 wet days at Southern Cross, 19.9 at Coolgardie, and 16.5 at Kalgoorlie. The average 1941-50 winter had 23.8 wet days at Southern Cross, 23.5 at Coolgardie and 21.8 at Kalgoorlie. A striking aspect of this change is that whereas during 1931-40 there was a decrease of 11.5 in the frequency of winter wet days from Southern Cross to Kalgoorlie, during 1941-50 the decrease was reduced to 2. The change during these two decades had an equalizing effect.

THE TEMPERATURE OF PERTH

So much work has been done on changes of temperature in the Northern Hemisphere that it was thought desirable to analyze the temperature of Perth in order to find whether there had been any significant change. Because of the change of location from Government Gardens to the Observatory, records were compared for the two localities and for the same period, 1897-1926.

TABLE 9.—MEAN TEMPERATURE OF PERTH.

Month	Govt. Gardens	Observatory	Diff.
January	74.8	73.8	1.0
February	74.7	74.0	0.7
March	71.9	71.2	0.7
April	66.9	66.6	0.3
May	60.8	60.6	0.2
June	56.8	56.8	0.0
July	55.4	55.2	0.2
August	56.4	55.9	0.5
September	59.0	58.2	0.8
October	62.0	60.8	1.2
November	67.4	66.2	1.2
December	71.7	70.6	1.1

It is clear that the difference is significant because it follows a definite trend and its magnitude is far from negligible in spring and summer, but no explanation of its cause is attempted here.

A study in trends gives the following results.

TABLE 10—COMPUTED MEAN MONTHLY TEMPERATURES, PERTH

Month	Government Gardens 1876	Government Gardens 1926	Government Gardens Diff.	Perth Observatory 1897	Perth Observatory 1945	Perth Observatory Diff.
January	75.39	74.01	−1.38	73.81	73.79	−0.02
February	76.13	73.47	−2.66	73.66	74.34	+0.68
March	72.94	71.26	−1.68	70.92	71.48	+0.57
April	66.07	67.13	+1.06	66.50	66.70	+0.21
May	60.08	61.12	+1.04	60.21	60.99	+0.77
June	55.57	57.63	+2.06	56.20	57.10	+1.19
July	54.57	55.63	+1.06	55.07	55.33	+0.25
August	56.29	56.31	+0.02	55.51	56.29	+0.78
September	58.91	58.89	−0.02	57.96	58.44	+0.49
October	62.78	61.01	−1.77	60.62	61.42	+0.36
November	68.36	66.84	−1.52	65.05	67.35	+2.30
December	72.16	71.24	−0.92	70.18	71.02	+0.83

It is clear from the preceding table that winters are warmer than in the recent past, although the exact magnitude of the change cannot be known. An attempt to combine the records for the two localities on record after having allowed for the difference between their temperatures as disclosed by the comparison made above gives the following result:

TABLE 11.—ESTIMATED MEAN MONTHLY TEMPERATURES, PERTH.

Month	1876	1947	Diff.
January	74.4	73.7	−0.7
February	75.4	74.3	−1.1
March	72.2	71.4	−0.8
April	65.8	66.8	+1.0
May	59.9	61.1	+1.2
June	55.6	57.4	+1.8
July	54.4	55.3	+0.9
August	55.8	56.3	+0.5
September	58.1	58.6	+0.5
October	61.5	61.1	−0.4
November	67.2	67.4	+0.2
December	71.1	71.3	+0.2

The annual range of temperature, which is estimated at 21° F. for 1876, would only be 19° F. for 1947. All told, winters are very slightly warmer than they used to be, and summers perhaps a little less hot. The climate is perhaps a little less continental than it used to be.

THE CLASSIFICATION OF CLIMATE

No analysis of types of climate over a long period has been carried out in Western Australia, but two studies, the one tabular, and the other geographical, cover shorter periods and are worthy of notice.

A computation by Mr. N. P. Rudeforth of the index of precipitation effectiveness for Mount Barker during a period of 15 years shows an increase in humidity. During the first 7 years the climate was twice humid (B5), three times subhumid wet (C4), once subhumid dry (C3), and once semiarid (D2). During the last 7 years the climate was four times humid (B5), twice subhumid wet (C4), and once subhumid dry (C3).

TABLE 12.—PRECIPITATION EFFECTIVENESS, MOUNT BARKER

Year	J.	F.	M.	A.	M.	J.	J.	A.	S.	O.	N.	D.	Annual Total	Climate
1936	1.2	.5	.2	1.8	7.0	8.2	7.2	6.0	3.0	3.5	1.2	1.8	41.6	C3
1937	1.2	.1	4.0	3.6	12.0	4.5	6.5	8.8	6.2	4.0	2.0	.8	53.7	C4
1938	.8	.2	2.6	3.0	9.5	8.2	10.5	4.5	3.0	3.5	2.5	.8	49.1	C4
1939	11.5	2.5	.6	3.0	5.2	9.4	7.6	9.0	1.5	11.0	5.2	.2	66.7	B5
1940	.9	.2	.3	1.8	2.8	3.5	7.0	4.0	4.0	1.8	1.5	2.8	30.6	D2
1941	.5	.3	9.5	3.2	4.6	6.5	7.5	5.8	9.5	5.2	2.5	.2	55.2	C4
1942	.8	.2	6.5	4.8	9.5	10.0	10.5	10.8	6.5	6.5	1.8	5.0	72.9	B5
1943	2.2	2.2	6.5	5.0	4.8	4.8	14.0	7.5	5.0	1.0	1.0	1.5	55.5	C4
1944	.2	1.2	.6	2.0	6.8	3.5	9.5	7.0	4.8	1.0	2.0	3.0	41.6	C3
1945	.2	0	4.5	1.5	7.0	15.8	11.2	14.8	9.5	3.0	2.2	1.8	71.5	B5
1946	.2	.2	1.0	2.0	8.0	9.4	10.0	6.0	3.6	2.5	5.0	2.5	50.4	C4
1947	.2	1.5	.6	19.0	.3	15.0	7.5	5.0	5.8	12.0	5.2	.2	72.3	B5
1948	.1	.2	.7	4.0	1.8	5.0	10.0	8.5	6.8	3.5	6.2	2.5	49.3	C4
1949	.8	.1	2.0	2.4	4.5	6.2	14.0	11.8	4.2	13.0	5.8	.2	65.0	B5
1950	1.0	.2	.1	.1	23.0	8.0	10.5	6.5	7.5	6.5	3.5	1.0	67.9	B5

The geographical study of climate carried out by Messrs. Graham, Russell and Vance consisted of an analysis of Western Australian climates according to Koeppen's method. The maps thus obtained (Figs. 2 and 3) show humid climates black, semiarid climates ruled, and arid climates white. In this case it is not possible to detect a trend, which only a statistical-historical method could disclose, but considerable annual variations are noticeable within the established pattern.

Has the climate changed? It undoubtedly has, but for how long remains to be seen. Another problem to be solved is that of the cause of these changes, and it is hoped that some results may be obtained by further research.

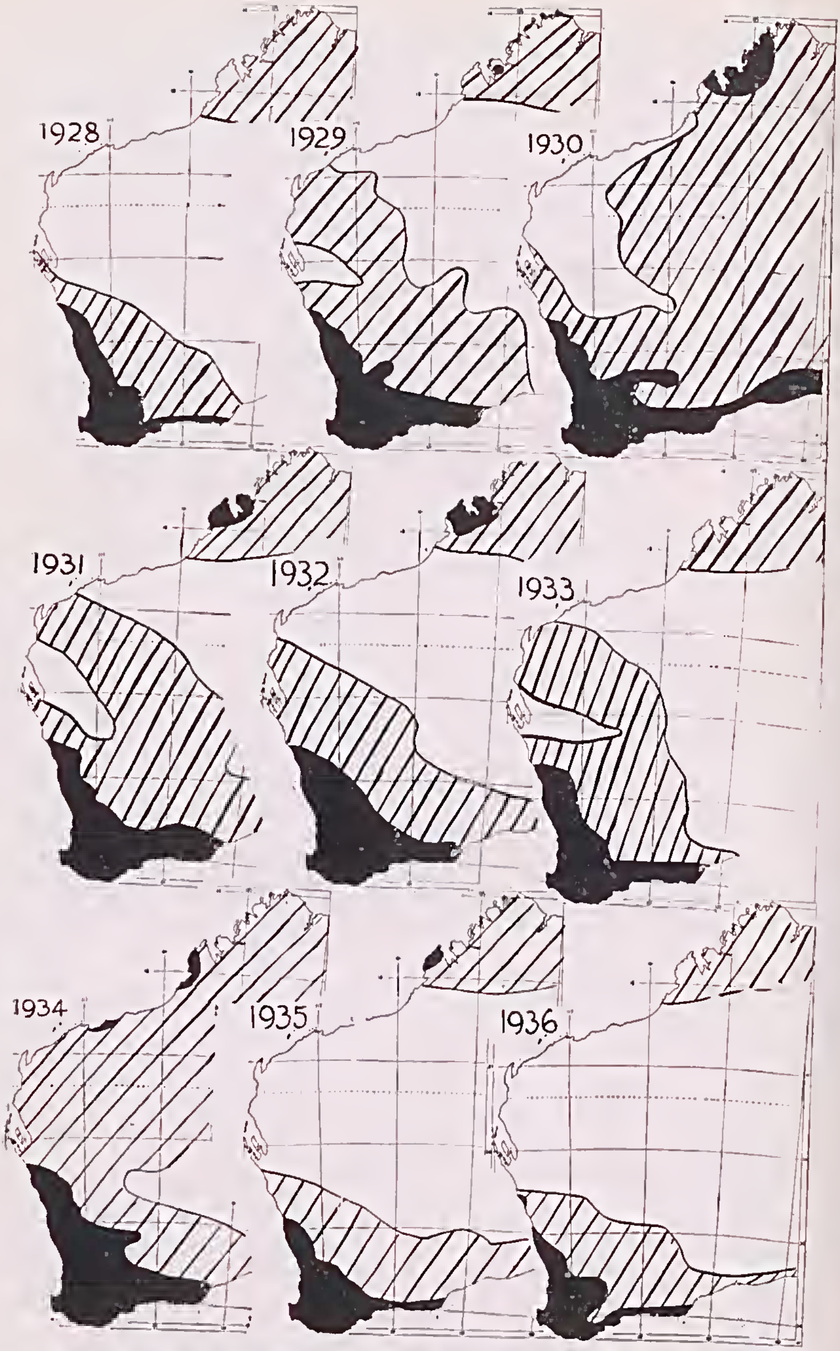

Fig. 2.—The climates of Western Australia for each year since 1928. The humid areas are shown black. The semiarid areas are shaded, and the arid areas are white; the classification of climates used is that of Koeppen.

Fig. 3.—Western Australian climates, continued.